5 ФТ

NASA

NASA-CR-174044

E85-10021

164000-11-P

Seventh Type II Quarterly Status
and Technical Report

STUDY ON SPECTRAL/RADIOMETRIC CHARACTERISTICS OF THE THEMATIC MAPPER FOR LAND USE APPLICATIONS

21 March 1984 — 20 June 1984

WILLIAM A. MALILA
MICHAEL D. METZLER

AUGUST 1984

Contract NAS5-27346
NASA Goddard Space Flight Center
Greenbelt Road
Greenbelt, Maryland 20771

ENVIRONMENTAL
RESEARCH INSTITUTE OF MICHIGAN
BOX 8618 • ANN ARBOR • MICHIGAN 48107

Report No. 164000-11-P

Seventh
Type II Quarterly Status
and Technical Progress Report
21 March 1984 – 20 June 1984

for

Study on Spectral/Radiometric Characteristics of the Thematic Mapper for Land Use Applications

under

Contract NAS5-27346

with

NASA Goddard Space Flight Center
Greenbelt Road
Greenbelt, Maryland 20771

Submitted by

Environmental Research Institute of Michigan
P.O. Box 8618
Ann Arbor, Michigan 48107

Prepared by: ______________________
William A. Malila
Principal Investigator

____
Michael D. Metzler
Co-investigator

Approved by: ______________________
Robert Horvath
Manager, Information Processing Department

August 1984

Table of Contents

Seventh Quarterly Report

STUDY ON SPECTRAL/RADIOMETRIC CHARACTERISTICS OF THE THEMATIC MAPPER FOR LAND USE APPLICATIONS

1. OBJECTIVE

The objective of this investigation is to quantify the performance of the TM as manifested by the quality of its image data in order to suggest improvements in data production and to assess the effects of the data quality on its utility for land resources applications. Three categories of this analysis are: a) radiometric effects, b) spatial effects, and c) geometric effects, with emphasis on radiometric effects.

2. TASKS

Four tasks have been established to address the above objective. The first three are to study radiometric performance, spatial performance, and geometric performance, respectively, while the fourth is to study spectral characteristics. In keeping with the identified objective, the radiometric performance study is our major task.

3. STATUS AND TECHNICAL PROGRESS

3.1 PROBLEMS

None.

3.2 ACCOMPLISHMENTS

A first-look screening was conducted of image data from the first Landsat-5 scene we received, after computer software was designed, implemented, and tested to allow reading of TIPS-format CCTs with an IBM-compatible mainframe computer. Analysis was resumed of the 'droop' effect reported earlier in Landsat-4 TM data.† Nighttime scenes as well as daytime scenes were examined in detail to quantify the effect. A new mathematical model was developed based on a potential physical explanation of the effect, and was fit to the scene data. Coherent noise of a lower frequency than reported before was discovered and analyzed. Coincident Landsat-4 TM and MSS data were analyzed to gain understanding of radiometric relationships between similar TM and MSS wavebands. Details of these analyses are provided below.

3.2.1 First-Look Screening of Landsat-5 Image Data

Quantization-level histograms were produced for the Corpus-Christi four-band frame of TM imagery, the only Landsat-5 scene received to date (see Figure 1). Although these histograms are obviously very dependent on scene content, their shapes are consistent with what would have been expected from Landsat-4 TM for the same scene. As with Landsat-4, saturation occurs in Bands 1 and 3 over cloud areas, with most of the non-cloud data occupying a narrower region of the 8-bit quantization range. Band 4 data exhibit some of the bi-modal distribution of digital count values that would be expected in scenes which contain both water and vegetated areas. Because this is a fully corrected data set (CCT-PT), analysis of individual detector responses and quantization characteristics can not be performed. These analyses will await receipt of tapes without geometric correction (CCT-AT) and, hopefully, tapes without radiometric correction (unity RLUT CCT-AT).

3.2.2 Analysis of Scan-Direction Related Signal Droop Effect

Earlier investigation suggested the presence of a scan-direction related effect which caused the mean signal level to decrease as the scan progressed in time.† As observed in an early North-Central Iowa scene (40049-16262), the effect was most apparent in Band 1 where the mean signal decayed approximately one count as the

----

†Malila, W. A., and M. D. Metzler, "Study on Spectral/Radiometric Characteristics of the Thematic Mapper for Land Use Applications", ERIM Report 164001-1-T, 1982.

scan progressed. Precise quantification of the effect was found to be difficult, as scene-related scan-angle effects were also present at a magnitude five to six times greater than the magnitude of the 'droop'.

In our resumed analysis of this 'droop' effect, data collected at night with the reflective bands were examined in order to eliminate any scene-related scan-angle effects (bi-directional reflectance, atmospheric backscattering, etc.). In these data the scan-direction effect clearly stood out after high-frequency noise components were filtered out. The filtering was accomplished through the use of a sliding-window median filter with a variable window size to separately compute 'average' forward and reverse scan lines. The 'average' forward scan was derived by computing the mean signal value at each pixel position for all 2992 forward scan lines in the scene. The 'average' reverse scan was computed in the same manner using all reverse scans in the scene.

Applying the filter to these average scans of night data revealed an unmistakable, if small, droop effect in Bands 1-4. Figures 2-8 illustrate the filtered average forward and reverse scans for the two night scenes analyzed, Buffalo (40037-02243), and Augusta (40161-02481). In this case the observed 'droop' is actually a 'rise', or increase in mean signal with time. Quantification of the 'droop' effect in the Iowa scene (40049-16262) data involved analysis of the difference between 'average' forward and reverse scans to reduce the scene-dependent scan-angle effects present in the data. Figure 9 is a plot of this difference for Band 1 of the Iowa scene data.

The 'rise' effect observed in the night data is quite small (<0.10 DN). However, in the daytime data, the 'droop' is >1.0 DN for Band 1. In fact, the magnitude of the effect is seen to be approximately proportional to the mean signal level. The observed relationship between 'droop' magnitude and mean signal level, together with the apparent exponential character of the 'droop/rise', led to the development of a simple mathematical model for analysis of the effect. This model is expressed by the equation:

$$S(p) = S_0 + Be^{-p/T}$$

Where:

$S(p)$ = signal returned by sensor for pixel 'p'
S_0 = signal for 'p'equal to infinity
B = magnitude of total 'droop/rise'
T = time (pixels) required for signal to change by 63% of 'B'
p = pixel number, with count starting with first image pixel (West-most for forward scans, East-most for reverse daytime scans)

Applying this model to the two night scenes analyzed yielded time constants of approximately 900 pixels for Bands 1, 2, and 3, both forward and reverse scans.

The time constant for Band 4 was found to be approximately 1100 pixels for both scan directions. The parameter 'B'is seen to be related to the difference between the *scene* mean signal (image data) and the *overall scan* mean signal (image + shutter + calibration pulse). This relationship between 'B'and mean signal levels describes both the daytime 'droop', when the mean signal level of the image data is greater than the mean of (image + shutter + calibration), and the 'rise' observed at night, when the image and shutter data are all at very low signal levels and the calibration pulse raises the *overall scan* mean signal.

A plausible physical explanation of this effect is that the 900-1100 pixel time constants represent the AC coupling characteristics of the signal channels. These effects could persist through the DC restore circuitry which periodically clamps the output voltages to a reference level through capacitors with much larger time constants.

The bands on the cold focal plane (Bands 5-7) did not exhibit the same 'droop' effect observed with the primary focal plane sensors (Bands 1-4). This is not unreasonable since they have different sets of electronics from the primary focal plane detectors. Band 5 and 7 data had a very small effect in a direction opposite to that observed for Bands 1-4, 'drooping' during the nighttime observations.

Band 6 data were more difficult to characterize than were data from the reflective bands since the energy detected by Band 6 sensors is thermal radiation instead of reflected solar irradiance, and therefore is present both day and night in significant quantities. To characterize the scan-direction effect for Band 6, a differencing operation similar to that used for daytime reflective data was used. This procedure produced the results illustrated in Figure 10. As can be seen from the figure, this effect is neither a 'droop' nor a 'rise', and is not described by the exponential model.

3.2.3 Coherent Noise in Nighttime Data

Examination of the filtered 'average' forward and reverse scans from the nighttime reflective data (Figures 2-7) leads to several observations:

1. A low-amplitude periodic noise with a period of 262-264 pixels (~400 Hz) is superimposed on the signal 'droop'.
2. This periodic noise is in phase for all bands and channels, and apparently is in phase for all scan lines in the frame.
3. Some apparently anomalous but consistent features in the periodic noise pattern are observed in both scenes and in more than one band, i.e., an amplitude spike at approximately Pixel 1000 in forward scans of all four bands, a phase shift in Band 1 forward scans at Pixel 3100, an apparent gain increase (decrease) in Band 1 (2,3) reverse scans at Pixel 4500, an amplitude spike at Pixel 4600 in Band 5, etc.

The magnitude of this noise is as much as 0.75 DN in unfiltered Band 1 nighttime

data, but the filtering process reduces it to very low levels (<0.05 DN). Similar noise has not been observed in daytime scenes containing actual reflective data with the resultant higher mean signal levels. The source of this noise has not been determined.

3.2.4 TM and MSS Radiometric Correlation

Simultaneous TM and MSS coverage of North Carolina scene 40070-15084 (WRS path 14, row 36) on 24 September 1982 provided an opportunity to compare the radiometry of similar wavebands on the two sensors over a diverse set of targets. This scene contains areas of native vegetation, very large (1-mile square) cultivated areas of various crops in varying stages of development, and part of the North Carolina coastal area. Relatively homogeneous areas were selected from the scene classes of water (both deep and shallow), wet and dry soil, deciduous and coniferous forest stands, field crops (ranging from bare soil to green to senescent to post-harvest residue), concrete, and beach sand. Fourteen areas were selected which covered this range of scene classes, and mean signal values were computed for each of the areas for Bands 1 through 4 of both sensors. Correlations between bands were computed, as were linear regressions of similar bands:

MSS1(0.5-0.6um) vs TM2(0.52-0.60um)
MSS2(0.6-0.7um) vs TM3(0.63-0.67um)
MSS3(0.7-0.8um) vs TM4(0.76-0.90um)
MSS4(0.8-1.1um) vs TM4(0.76-0.90um)

The regression and correlation coefficients are presented in Table 1, Figures 11-14 illustrate the relationships between radiometrically similar wavebands.

Although the selected targets do not span the full dynamic range of any of the bands, they do cover much of the signal count range encountered by these sensors in landcover remote sensing. It is clear from these figures that in this very useful signal count range there exist linear relationships between similar bands of the two sensors. A potential use of these relationships is the conversion of TM data into MSS-equivalent data, allowing continued use of procedures which have been tuned to MSS signal values.

3.3 SIGNIFICANT RESULTS

See section 3.2.

TABLE 1. Landsat-4 TM-MSS Regressions (24 September 1982, North Carolina data)

$$MSS = A \cdot TM + B$$

Bands						Range of Data Values	
MSS	TM	A	B	S.E.	R^2	MSS	TM
1	2	0.7321	−0.411	0.496	0.9969	14-44	20-60
2	3	0.6952	−3.316	0.514	0.9984	7-48	15-73
3	4	0.6579	1.078	4.674	0.9724	3-72	8-117
4	4	0.3151	−1.396	0.433	0.9989	1-35	8-117
4'	4	0.6303	−2.792	0.866	0.9989	2-70	8-117

Note: MSS Band 4 values were multiplied by 2 after 20 October 1982; the relationship labeled MSS 4' applies to such data.

3.4 PUBLICATIONS AND PRESENTATIONS

A paper entitled "Thematic Mapper Radiometric Characterization" co-authored by William Malila and Michael Metzler was presented by W. Malila at the 1984 Purdue/LARS Symposium on Machine Processing of Remotely Sensed Data held 12-14 June, 1984. The symposium session on TM Data Quality Analysis was chaired by W. Malila.

3.5 RECOMMENDATIONS

None.

3.6 FUNDS EXPENDED

A total of approximately $25,000 was expended during the three months March through May 1984. The cumulative spending through May represents approximately 74% of the total contract award. Expenditures during the period 1-20 June 1984 are not included in this percentage value.

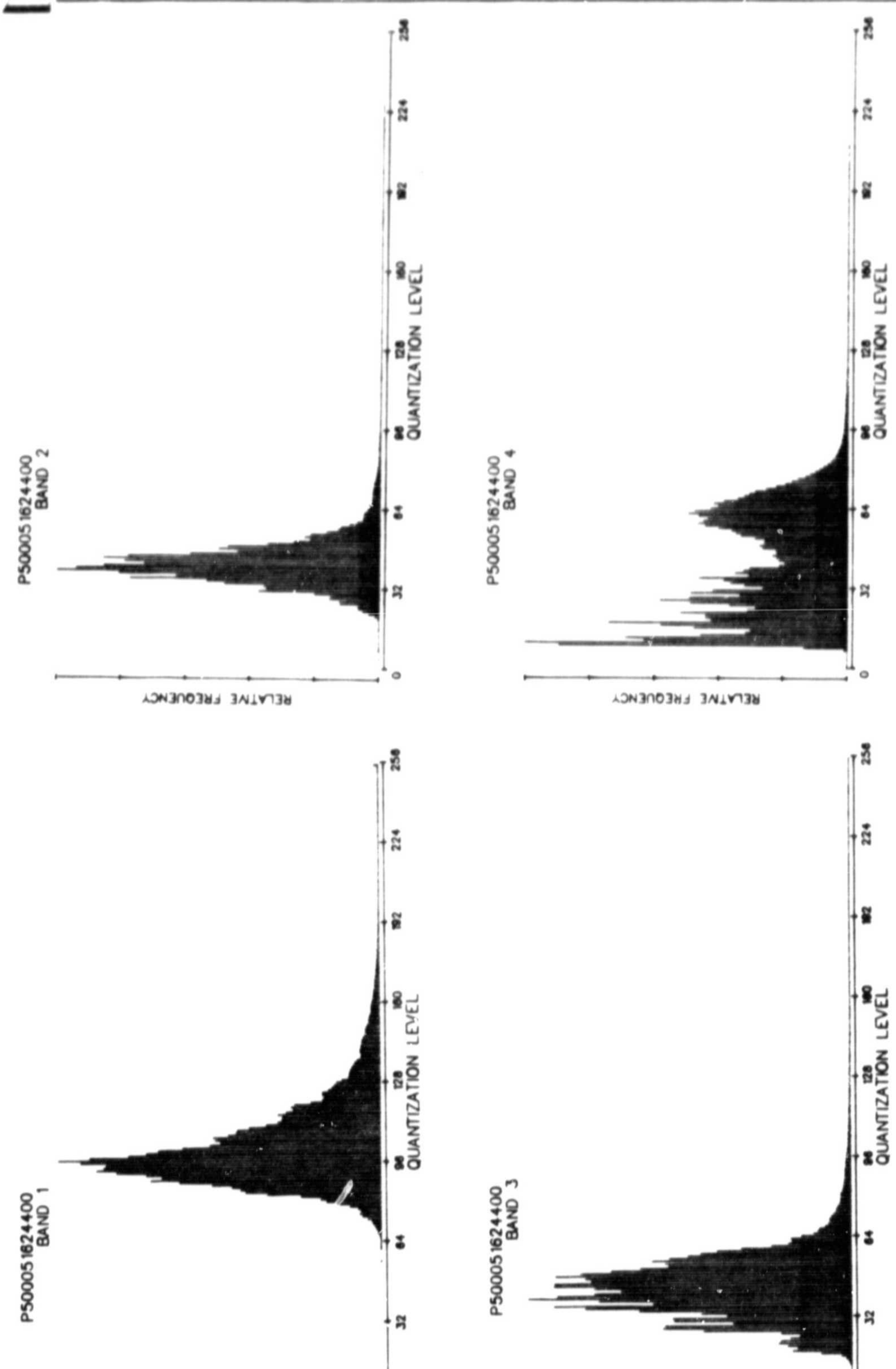

FIGURE 1. LANDSAT-5 TM QUANTIZATION HISTOGRAMS

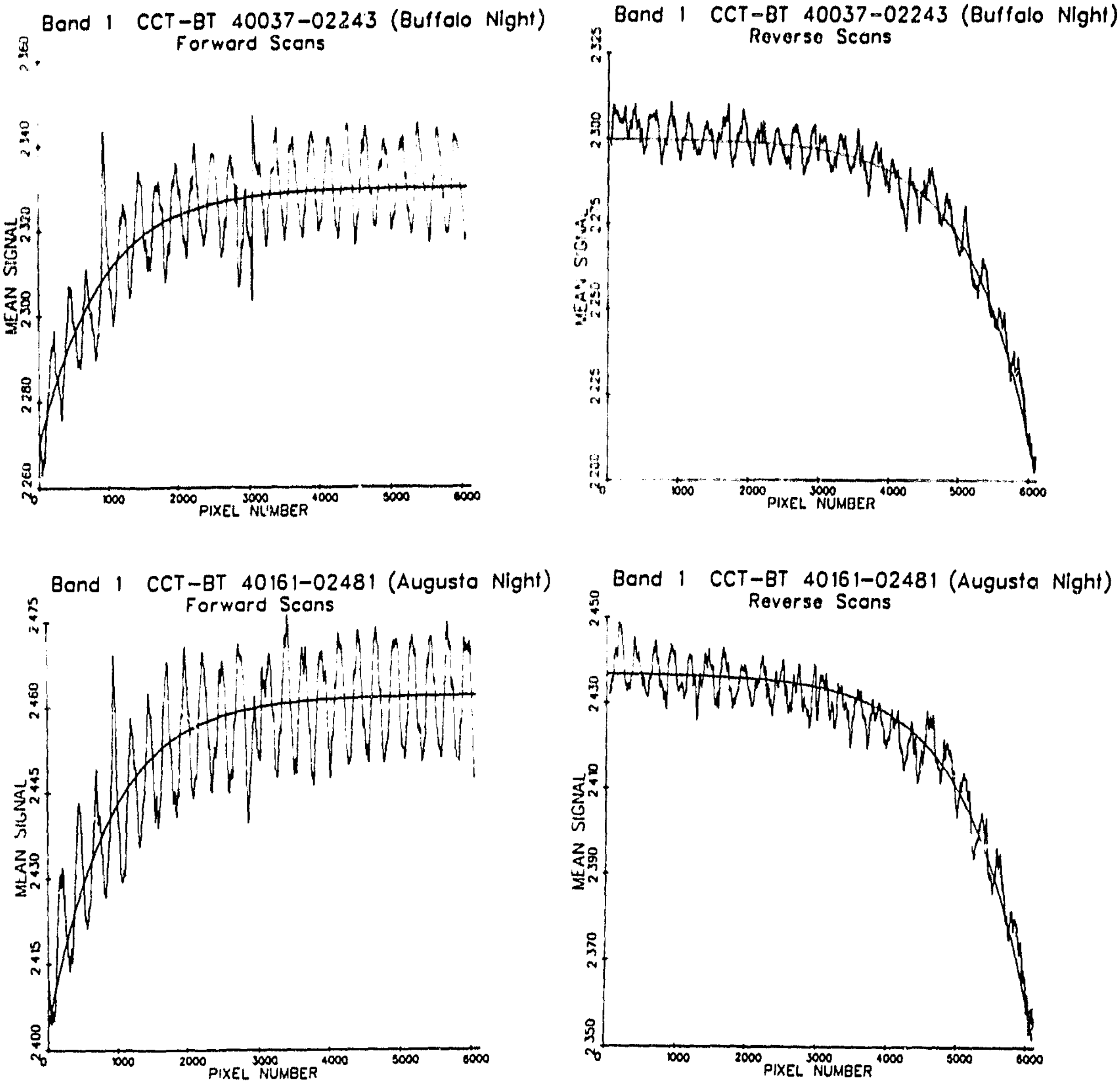

FIGURE 2. NIGHTTIME SCAN DIRECTION EFFECT, BAND 1

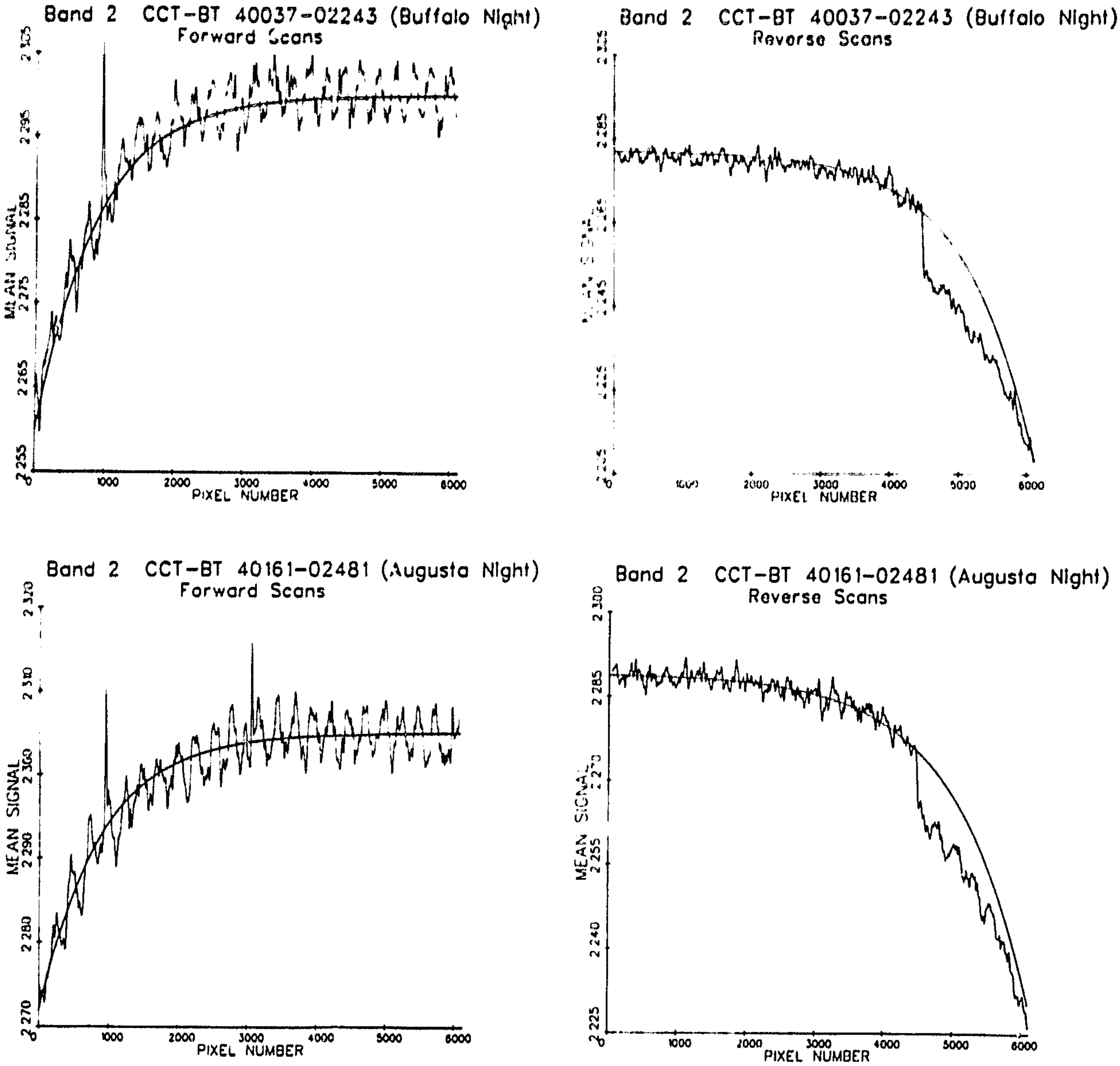

FIGURE 3. NIGHTTIME SCAN DIRECTION EFFECT, BAND 2

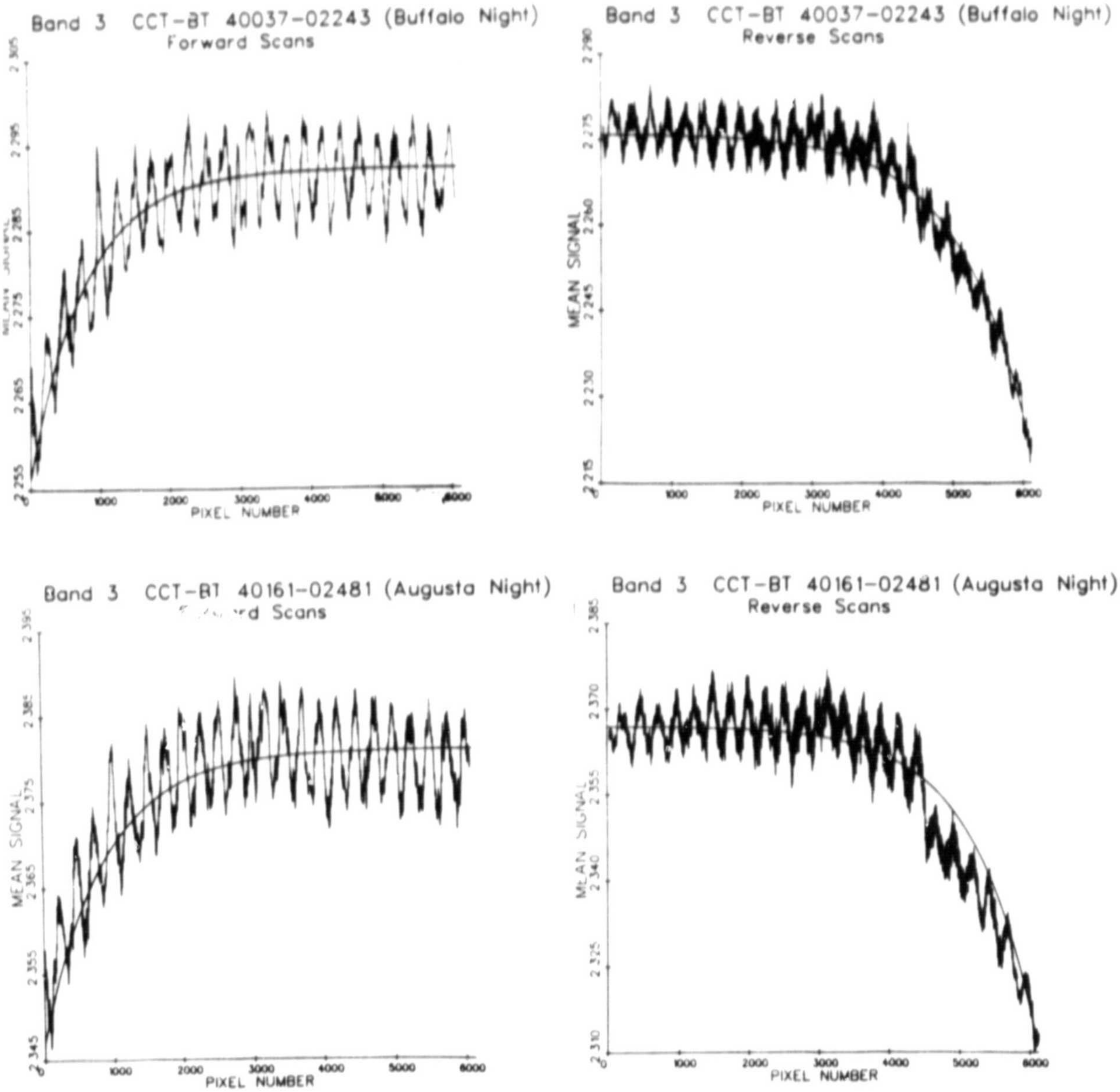

FIGURE 4. NIGHTTIME SCAN DIRECTION EFFECT, BAND 3

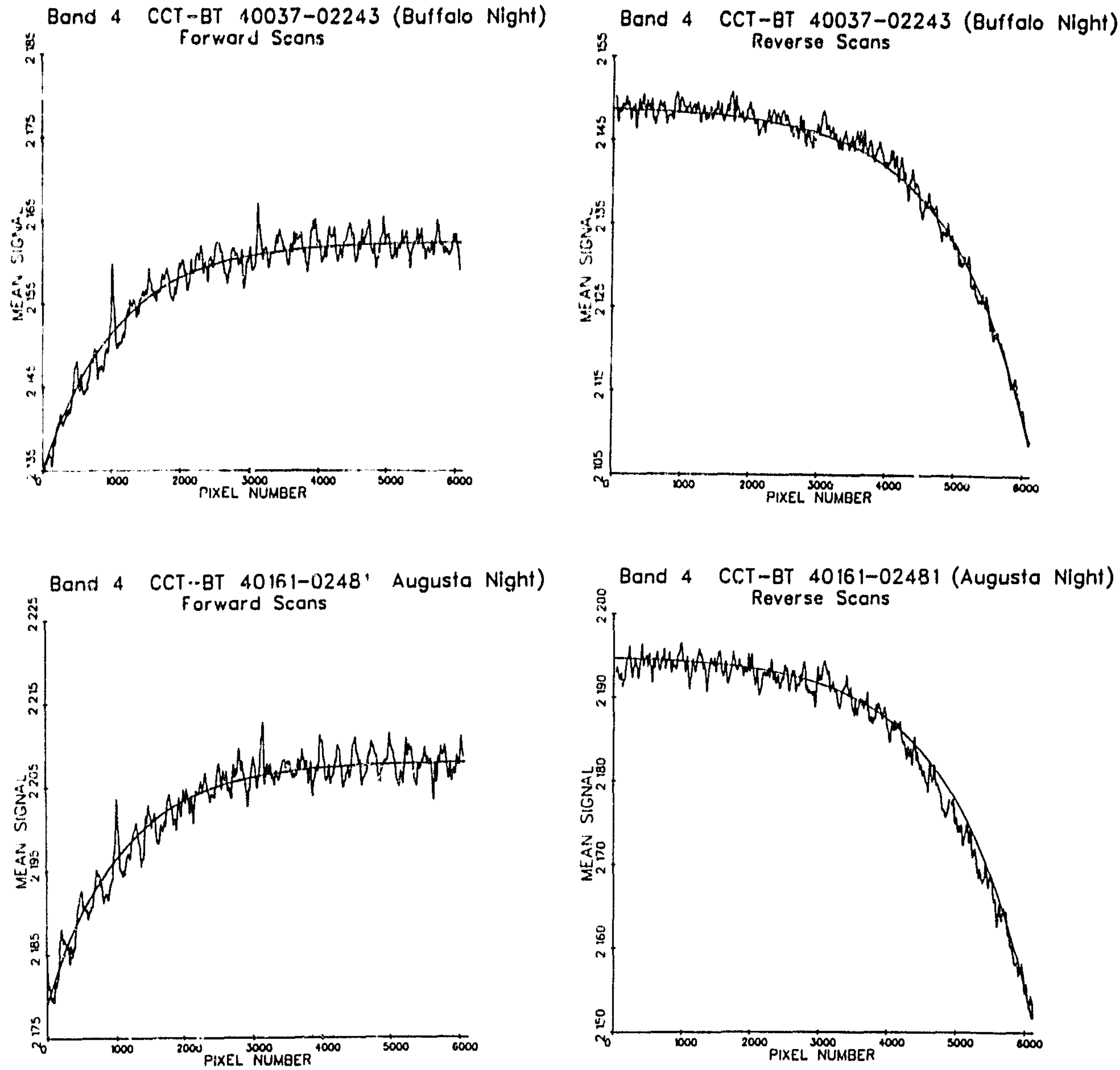

FIGURE 5. NIGHTTIME SCAN DIRECTION EFFECT, BAND 4

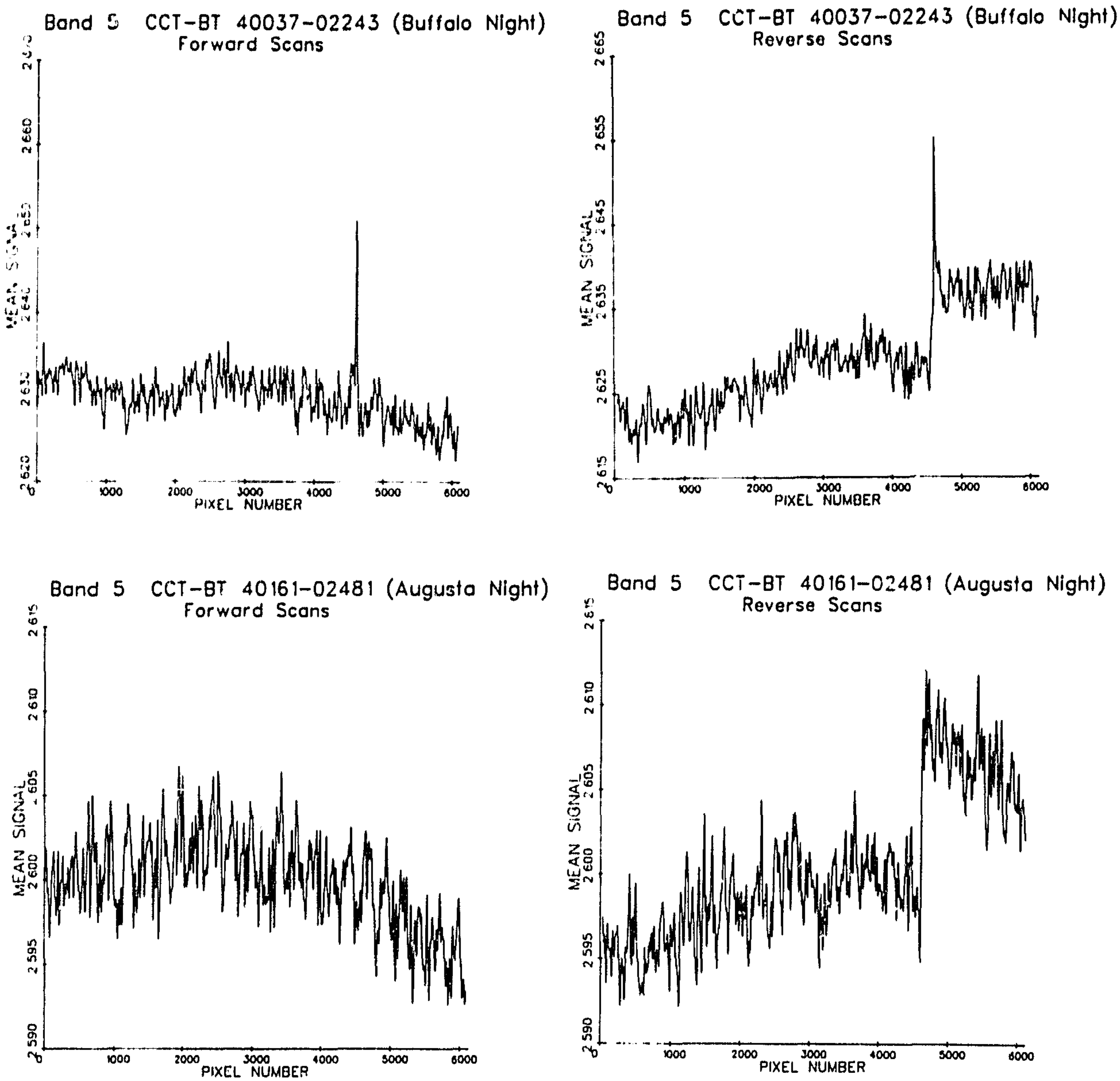

FIGURE 6. NIGHTTIME SCAN DIRECTION EFFECT, BAND 5

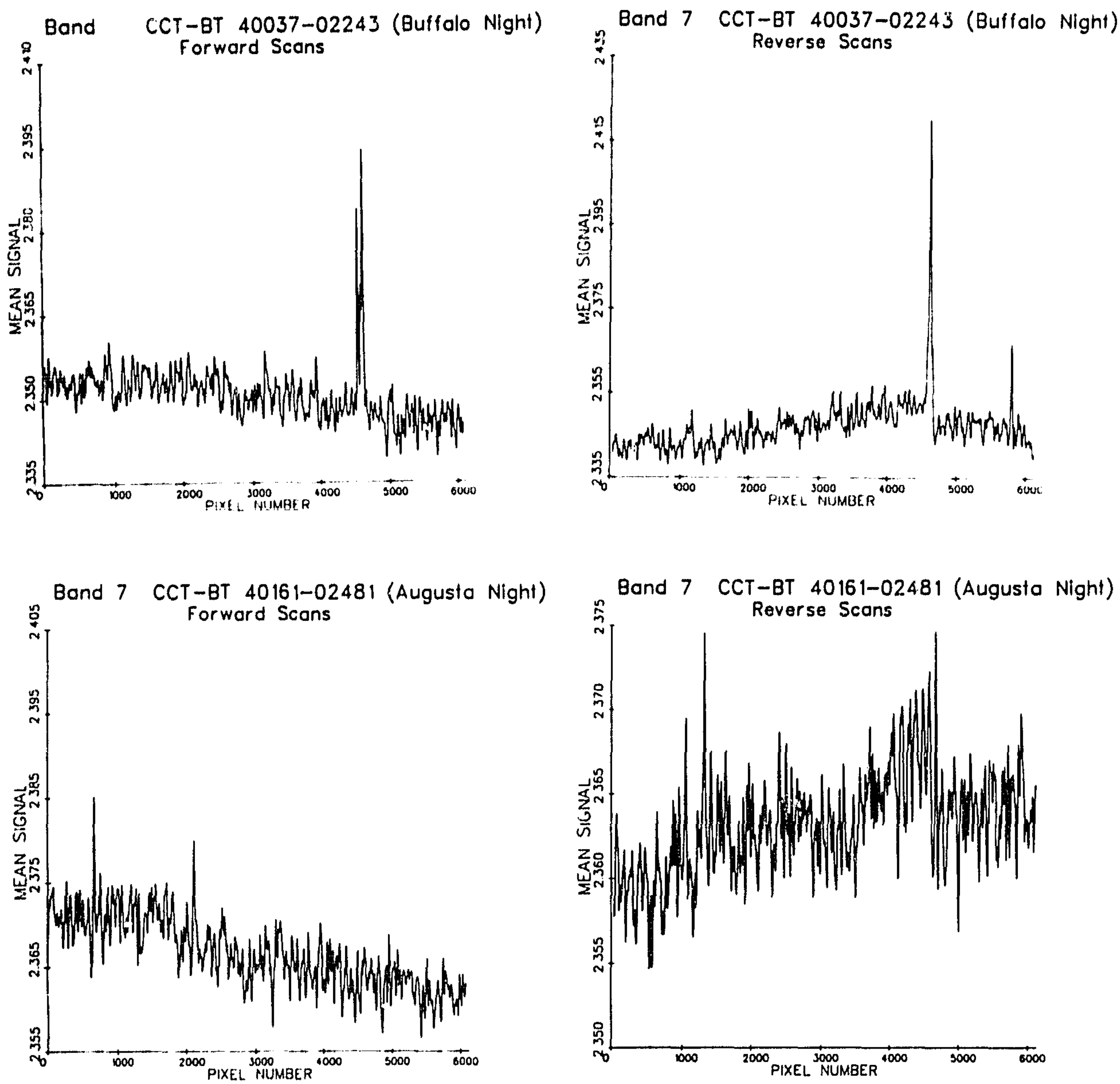

FIGURE 7. NIGHTTIME SCAN DIRECTION EFFECT, BAND 7

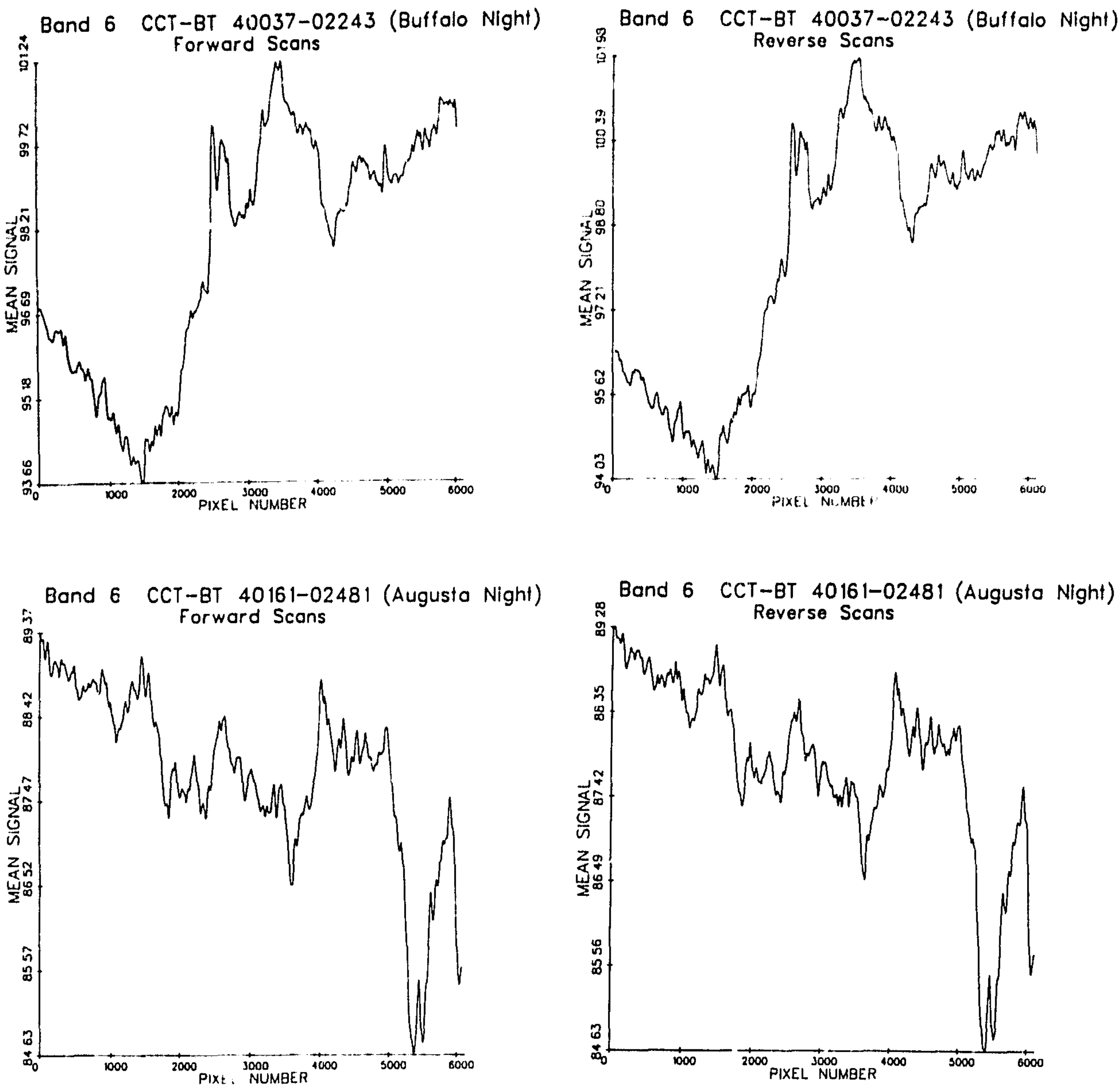

FIGURE 8. NIGHTTIME SCAN DIRECTION EFFECT, BAND 6

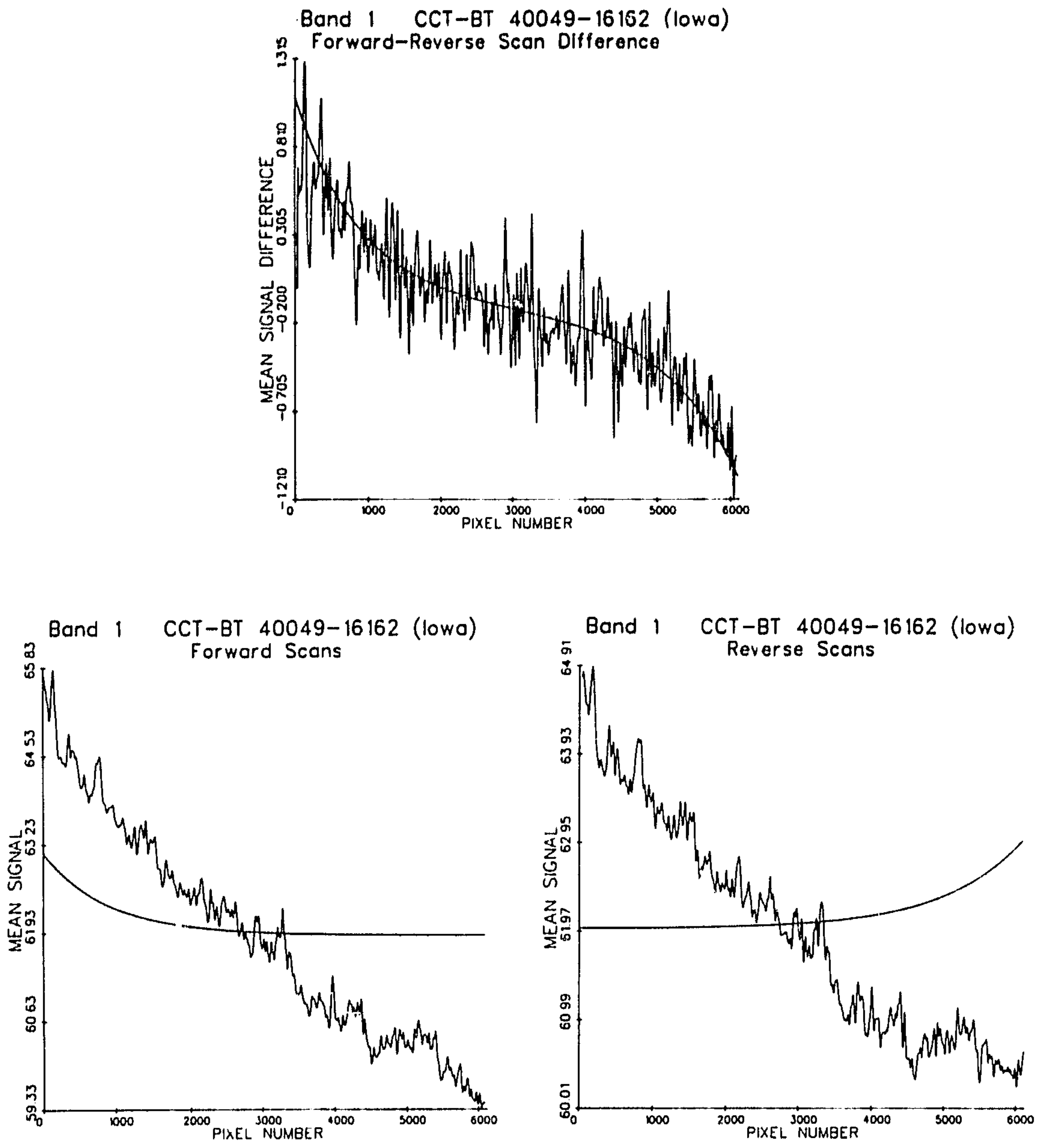

FIGURE 9. DAYTIME SCAN DIRECTION EFFECT, BAND 1

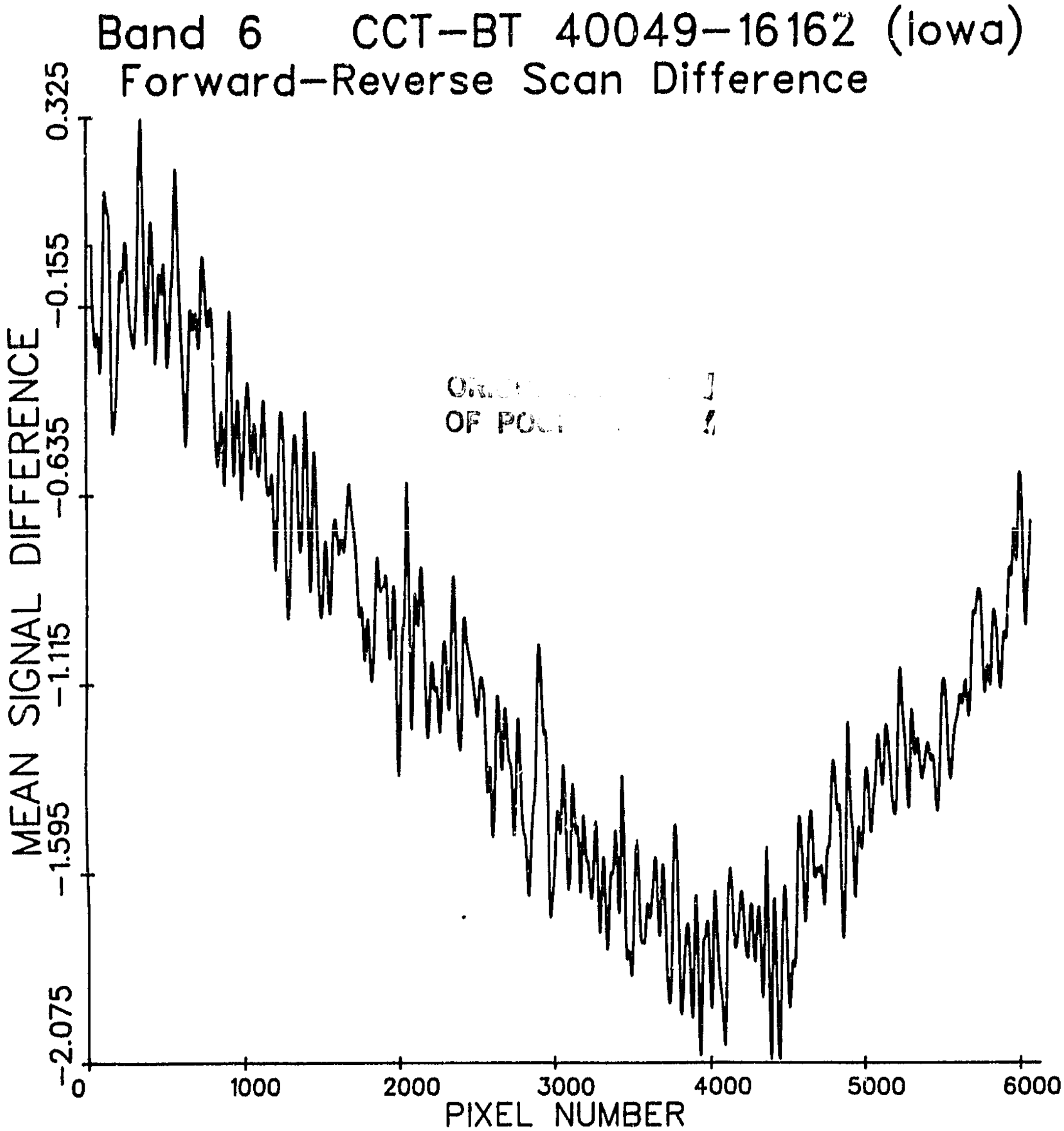

FIGURE 10. SCAN DIRECTION EFFECT, BAND 6

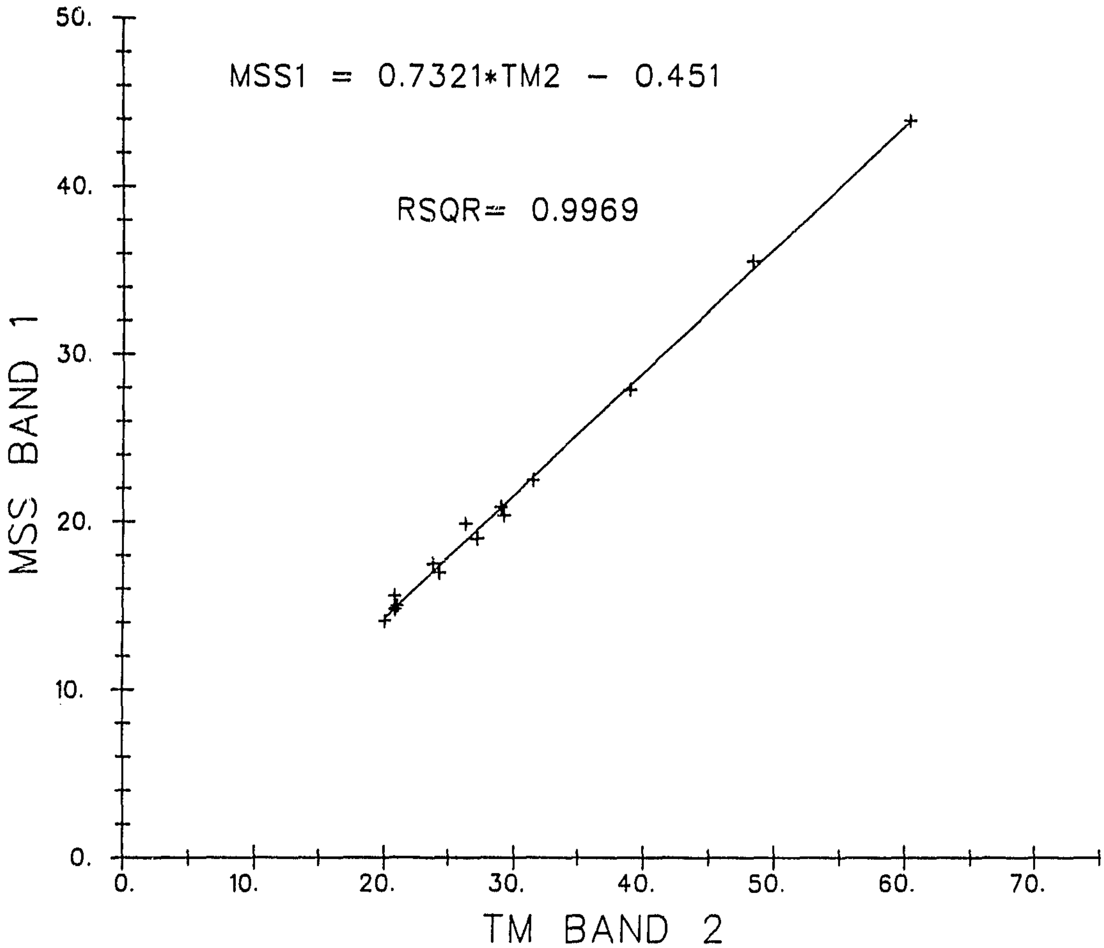

FIGURE 11. RELATIONSHIP BETWEEN MSS1 AND TM2 DATA

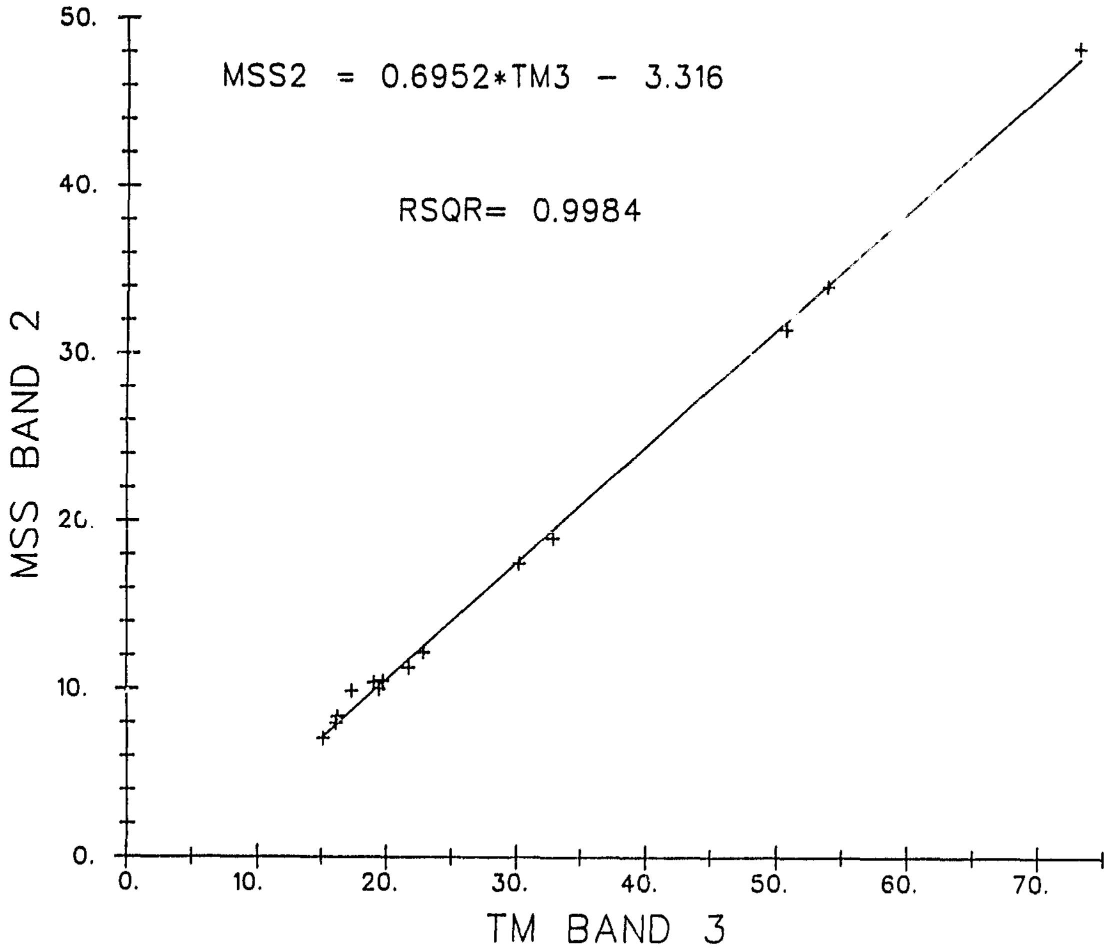

FIGURE 12. RELATIONSHIP BETWEEN MSS2 AND TM3 DATA

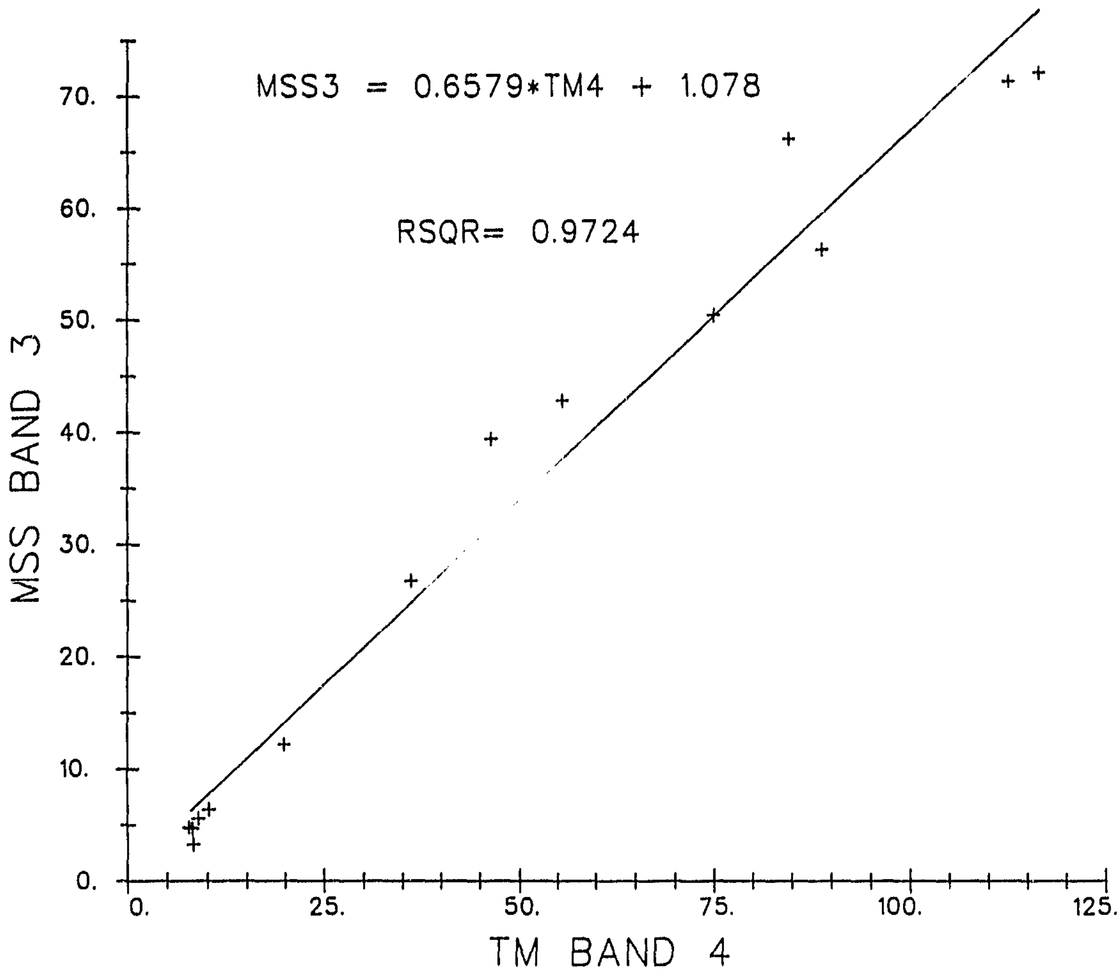

FIGURE 13. RELATIONSHIP BETWEEN MSS3 AND TM4 DATA

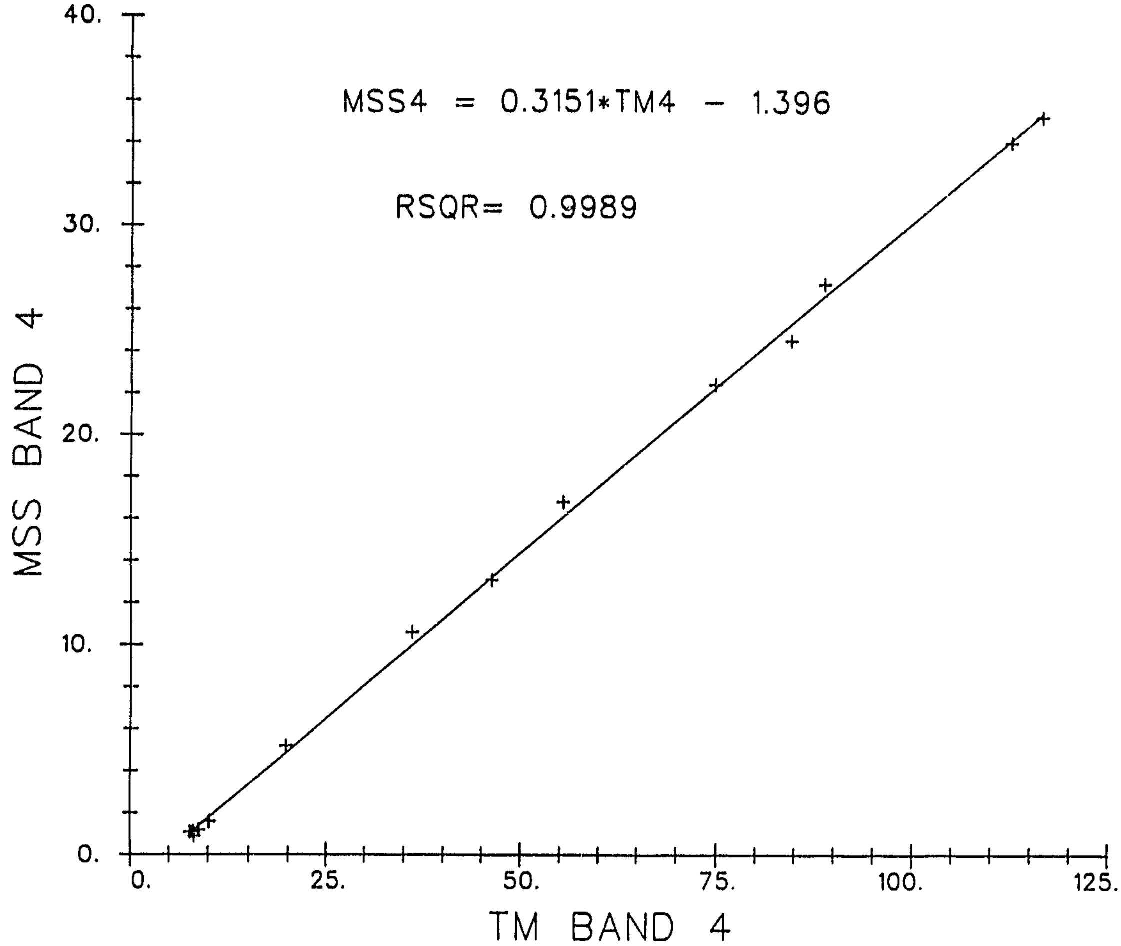

FIGURE 14. RELATIONSHIP BETWEEN MSS4 AND TM4 DATA